WOOD QUALITY OF SLASH PINE AND ITS EFFECT ON LUMBER, PAPER, AND OTHER PRODUCTS

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Abstract—The majority of timber harvested in the South, the woodbasket for the United States, is southern pine. Slash pine (*Pinus elliottii* Engelm.) is one of the more important pine species harvested. Its wood has high specific gravity, long tracheids, low microfibril angle, high alpha cellulose, and medium lignin content. The high specific gravity and branching habit of slash pine make it an excellent species for manufacturing dimension lumber. When planted at wide spacings, slash pine will produce a higher proportion of No. 1 and better lumber than loblolly pine (*P. taeda* L.) because of its natural pruning and smaller diameter branching habit. The tracheid characteristics of slash pine make it an excellent species for linerboard and sack paper production.

INTRODUCTION

The South is the woodbasket for the United States, producing 58 percent of the timber harvested in the United States and 16 percent of the World's timber harvest (Wear and Greis 2002). Most timber harvested in the South is southern pine, and slash pine (*Pinus elliottii* Engelm.) is one of the more important pine species. Its wood properties make it a desired species for manufacturing structural lumber, structural plywood, poles, pilings, posts, pulp, and paper products. This paper discusses those properties and considers why they are so important in lumber and paper production.

WOOD PROPERTIES

Slash pine wood consists principally of closely packed tracheid cells that run vertically up the stem, and parenchyma tissue or rays that extend horizontally from the pith toward the bark. Tracheids make up more than 90 percent of southern pine wood volume (Koch 1972) and, thus, the properties of the tracheids determine the properties of the wood. Tracheids are like long straws with tapered ends, and whose cell walls surround an air space or cell lumen. Cell walls have two major constituents—cellulose and lignin.

Because the specific gravity (SG) of cellulose is almost identical to that of lignin, the SG of cell wall substance is considered to be constant for all wood species. Thus, wood SG is an excellent and simple measure, independent of species, of a wood's total cell wall substance (Megraw 1985) and a moderate-to-high SG is universally accepted as a desirable wood quality trait. The cell wall of a mature tracheid consists of a primary wall or middle lamella, composed largely of lignin, and a secondary wall that has three layers: (1) the S_1 (outer), (2) S_2 (middle), and (3) S_3 (inner) (Koch 1972). The S_2, or secondary layer, makes up the bulk of the tracheid wall. Cave (1976) showed that the middle lamella and S_1 and S_3 layers remain essentially fixed, while variation in volume of the S_2 layer is solely responsible for change in tracheid wall thickness. The secondary wall layer consists of helically arranged cellulose microfibrils oriented in the long axis of the tracheid. The orientation of the microfibrils relative to the long axis of the tracheid is known as the microfibril angle (MFA). The MFA is an important property in determining the stiffness and dimensional stability of solid wood products.

When assessing wood properties of a species for end use, it is important to consider SG, tracheid length, MFA, alpha cellulose content, and lignin content. Each plays an important role in determining the suitability of a species for a specific end use (table 1). Slash pine mature wood has SG, tracheid length, MFA, alpha cellulose, and lignin contents that make it highly desirable for solid wood products, such as structural lumber and veneer. It also has wood properties that make it desirable for paperboard production, such as kraft paper and sack paper. Slash pine mature wood is less suitable for production of fine papers because of its long tracheids with thick walls and corresponding high SG.

The weighted stem SG of slash pine wood, when averaged across the species' geographical range, is 0.53, compared to 0.47 for loblolly pine (*P. taeda* L.) (Wahlgren and others 1975). The difference in SG between species is due to both genetic and environmental factors. The weighted stem SG of pine is determined by the amount of thick-walled, high

Table 1—Slash pine wood properties and desired wood properties for southern pine wood products

Species and product	Wood properties				
	Specific gravity	Tracheid length	MFA	Alpha cellulose	Lignin contents
Slash pine	High	Long	Low	High	Medium
Solid wood	High	Long	Low	High	Medium
Paperboard	High	Long	Low	High	Low
Fine paper	High	Short	Low	High	Low

MFA = microfibril angle.

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SG latewood tracheids produced each growing season. The natural range of loblolly pine is large and extends from Virginia to Texas and north to Tennessee and Arkansas, whereas the range of slash pine is smaller and extends only from the lower Coastal Plain of southeastern South Carolina to the eastern Gulf Coastal Plain of Louisiana. The SG of southern pines decreases from the Atlantic or gulf coast inland because the inland trees have less summer precipitation and a shorter growing season for latewood production (Clark and Daniels 2004). Thus, the SG of slash pine when averaged across its range is 11 percent higher than that of loblolly when averaged across its range. However, differences between the species are not as great when the species are growing in the same geographic region.

To minimize the effect of environmental factors or geographic location on SG, we sampled slash and loblolly pines planted in a study established by the Plantation Management Research Cooperative (PMRC) administered by the University of Georgia. That study's objective was to compare the growth of slash and loblolly pine when the two species are growing together at 141 locations in south Georgia and north Florida (Shiver and others 1996). Results of the PMRC study at age 14 show that loblolly pine produced more volume per acre, had better survival because of less *Cronartium* infection, and displayed less ice damage compared to slash pine. We felled three trees of each species in each of six stands at age 21. The diameter of the largest live or dead branch in each 8-foot section was recorded, and cross-section disks were harvested from along the stem for wood and bark SG, and moisture content determination. Preliminary results show that when the two species are growing together, the slash pine's weighted stem average SG was 4 percent higher than that of loblolly, and its SG average was 0.51 compared to 0.49 for loblolly. Thus, it appears that approximately 4 percent of the reported difference in species average SG is probably related to genetic or species differences and 8 percent is related to environmental factors.

When pine tree-length logs are purchased at a mill yard they are bought and sold on a weight basis, and a weight-scaling factor is used to convert the weight of a truckload of logs to cubic feet of wood. The weight-scaling factor is the weight of wood and bark per cubic foot of wood. Based on disks collected from the two species where they were growing together, we found that the slash contained 4 percent more dry wood because of its higher SG, 12 percent less water, and 3 percent more bark than the loblolly trees (table 2). The average weight-scaling factor for slash was 72.5 pounds per cubic foot compared to 70.4 pounds per cubic foot for loblolly when the two species were growing in the same stands. Although loblolly has a higher wood moisture content than slash pine, the weight-scaling factor for slash pine is higher because it has a higher SG and, thus, contains more oven-dry wood per cubic foot and more bark per cubic foot than loblolly.

Table 2—Average wood and bark properties for planted 21-year-old slash pine compared to loblolly pine when the species are growing in the same stand

Property	Slash pine	Loblolly pine
Wood specific gravity	0.51a	0.49b
Wood oven-dry weight per cubic foot (pounds)	31.9a	30.5b
Wood green weight per cubic foot (pounds)	63.0a	63.7a
Wood moisture content (percent)	97a	108b
Bark content (percent)	13.3a	9.8b

Within a property, values with a different letter are statistically different at the 0.05 level.

LUMBER GRADE YIELD

When visually grading southern pine structural lumber, one of the most important defects to evaluate is diameter of knots in relation to width of a board. In a No. 1 grade 2 by 4, the largest centerline knot allowed under southern pine dimension grading rules (Southern Pine Inspection Board 1994) is 1.5 inches width, and the largest centerline knot allowed in a No. 2 grade 2 by 4, is 2.0 inches. When growing in fully stocked stands, slash pine generally has smaller diameter branches and is a better natural pruner than loblolly pine, and, thus, it produces a greater proportion of higher grade lumber.

The diameter of the largest branch in each 8-foot saw-log stem section was plotted over stem height for 21-year-old slash and loblolly pine trees growing in the same stand planted at the same spacing (fig. 1). On average, the loblolly trees had larger diameter knots than the slash trees. Based on average maximum knot size, No. 1 or better 2 by

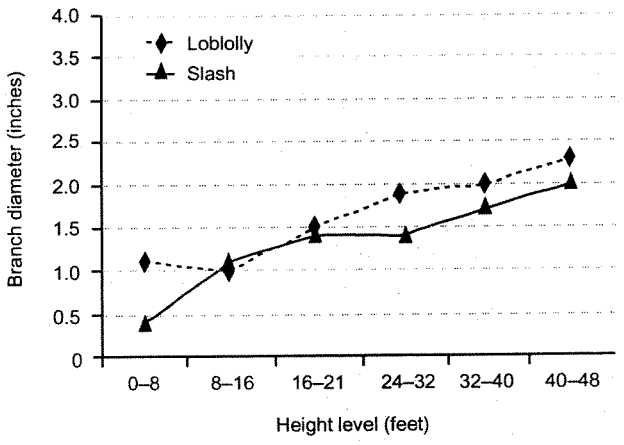

Figure 1—Average maximum branch diameter by 8-foot intervals up the stem of slash pine compared to loblolly pine when both species are growing in the same 21-year-old stand.

4 lumber could be manufactured from the butt 16-foot saw log of both species. The second 16-foot slash pine saw log could also produce all No. 1 and better 2 by 4 lumber; however, the second loblolly log would produce some No. 2 grade 2 by 4 lumber because of the knots > 1.5 inches in diameter. The third 16-foot slash log could produce all No. 2 and better 2 by 4 lumber; however, in the loblolly trees a portion of the 2 by 4 lumber from the third log would have to be trimmed back to remove knots larger than 2.0 inches to make No. 2 grade 2 by 4 lumber. Thus, the slash trees generally produced a higher proportion of No. 1 and better lumber.

The branching habit and natural pruning of slash pine also affect lumber yield, as illustrated in the lumber grade yield of a first thinning in a 17-year slash and 14-year loblolly pine stand.[2] The loblolly pine was planted at 600 trees per acre (TPA) in 1983 in a planting density plus competition control study on the University of Georgia, B.F. Grant Memorial Forest in the Piedmont of Georgia (Pienaar and Shiver 1993). In 1997, when the loblolly plantation was 14 years old, the study plots were marked for thinning. The slash pine trees came from the site-preparation and soil-type study planted in 1979 at 545 TPA by the PMRC in the lower Coastal Plain (Shiver and others 1994). The study was established at 20 sites ranging from Savannah, GA, to Apalachicola, FL.

In 1997, when the plantation was 17 years old, four trees from each of eight locations were marked for thinning from the site-preparation plus competition control study plots. The 32 loblolly and 32 slash trees were processed into 2- by 4-inch and 2- by 6- inch lumber at the same chipping sawmill on the same day. The lumber produced from each log was followed through the mill, kiln dried, planned, and graded using Southern Pine Inspection Bureau (Southern Pine Inspection Bureau 1994) lumber grades. When a board did not make a No. 2 or better, the reason for the downgrade was recorded.

Ninety-seven percent of the lumber produced from the 17-year slash pine was No. 2 or better compared to only 80 percent for the 14-year loblolly pine. The slash pine produced a significantly higher proportion of No. 1 and better, a lower proportion of No. 2, and a significantly lower proportion of No. 3 and No. 4 lumber compared to that of the loblolly pine (table 3). Three percent of the slash pine lumber and 3 percent of the loblolly lumber was downgraded below a No. 2 because of manufacturing defects (wane and skip). The proportion downgraded below a No. 2 because of drying defects (bow, twist, or crook) was 4 percent for loblolly compared to 2 percent for slash. Lumber that contains < 15 percent latewood is classified as exceptionally light weight and cannot be included in No. 2 nondense or higher grades of stress-rated lumber (Southern Pine Inspection Bureau 1994). Less than 1 percent of the slash pine lumber was downgraded because of insufficient latewood compared to 5 percent of the loblolly lumber. A significantly larger proportion of loblolly lumber was downgraded because of drying defects or insufficient latewood, because the loblolly trees were growing in the Piedmont and contained twice as much juvenile wood as the slash pine growing in the lower Coastal Plain (Faust and others 1999). The Piedmont loblolly pine produced juvenile wood with thin-walled tracheids, wide MFA, and a small proportion of thick-walled latewood tracheids for 9 to 10 years compared to the lower Coastal Plain slash, which produced juvenile wood for only 5 to 6 years. The difference in time until mature wood production is probably more related to physiographic region than to species. Clark and Daniels (2003) showed that loblolly pine grown in the Coastal Plain also transitioned to mature wood production in the 5- to 6-year range. Less than 0.5 percent of the slash pine lumber was downgraded below a No. 2 because of knot size, compared to 7 percent of the loblolly lumber. A significantly higher proportion of the loblolly lumber was downgraded, because the average loblolly log had more knots (24 knots vs. 17 knots for slash pine), and the maximum diameter knot was significantly larger for the loblolly (1.7 inches compared to 1.3 inches).

Table 3—Average proportion of dimension lumber produced by grade for 17-year slash pine planted at 545 TPA in the lower Coastal Plain compared to 14-year loblolly pine planted at 600 TPA in the Piedmont

Lumber grade	Slash pine	Loblolly pine
	percent	
No. 1 and better	53	21
No. 2	44	59
Nos. 3 and 4	3	20

TPA = trees per acre.

When loblolly pine is planted at wide spacings, the trees produce large diameter branches that result in a high proportion of No. 3 and worse lumber and a low proportion of No. 1 and better (Clark and others 1994). A simulated final harvest of loblolly pine at age 38 showed stands planted at 6 by 6 feet and thinned to ≤ 100 square feet basal area (BA) at age 18 produced ≥ 60 percent No. 2 and better lumber compared to ≤ 42 percent No. 2 and better lumber from stands planted 12 by 12 feet and thinned to the same BA. In contrast, when slash pine is planted at wide spacings and harvested at age 40, the trees produced 90 to 95 percent No. 2 and better lumber (fig. 2). When initial spacing is increased from 8 by 8 feet to 10 by 10 or 15 by 15 feet, the proportion of No. 2, No. 1, and dense grade lumber remains relatively constant because of slash pine's characteristic small diameter branches and early natural pruning.

[2] Clark, A., III; Shiver, B.D.; Pienaar, L.V. 2004. Effect of initial spacing and competition control on lumber grade yield of young fast-growing southern pine. 20 p. Unpublished report. On file with: A. Clark, III, U.S. Department of Agriculture Forest Service, Southern Research Station, 320 Green Street, Athens, GA 30602.

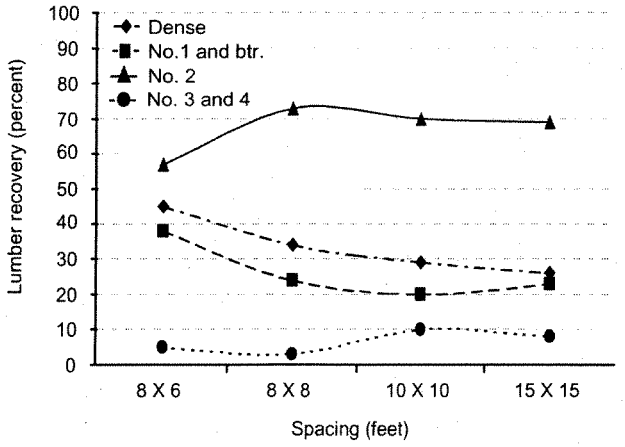

Figure 2—Effect of initial spacing on dimension lumber grade recovery for 40-year-old unthinned slash pine.

PULP AND PAPER YIELDS

Slash pine is not only an excellent species for structural lumber production, it is also good for linerboard and sack paper manufacturing. Wood for paper production can come from the whole stem, saw-log residues, or topwood above the saw-log stem. The 17-year-old slash pine trees harvested for lumber-yield analysis from the PMRC site-preparation and soil-type study were subsampled for pulp and paper analysis (Courchene and others 2000). Cross-section disks were cut at the butt, the top of each saw log, and from the 6-, 4-, and 3-inch diameter outside bark top. The chipping saw chips (CSC) were collected when the saw logs were sawn into lumber. The disks were chipped to provide pulp chips representing the whole tree and tops, and the CSC represented sawmill residue. The weighted whole stem SG averaged 0.52, saw-log stem SG averaged 0.53, and the topwood SG averaged 0.45. The SG of topwood was significantly lower because of the large proportion of thin-walled juvenile wood tracheids present. The packed bulk density, a measure of the weight of chips that can be packed into unit area for digesting, was highest for the whole stem (175 kg/m^3) and CSC (189 kg/m^3), and significantly lower for the topwood chips (157 kg/m^3).

One-half of the chips from each wood source were pulped in a batch digester to a kappa no. 90 for linerboard production, and the other half was pulped to a kappa no. 60 for sack paper production. Because slash pine is a high SG southern pine species, it has a high yield when pulped. Pulp yields for the kappa no. 90 cooks averaged 54 percent for the whole stem and CSC, compared to only 51 percent for the topwood chips. The pulp yields for the kappa no. 60 averaged only 47 percent for topwood compared to 50 percent for the whole stem and CSC. The weighted average tracheid lengths for the CSC, composed primarily of mature wood, averaged 4.1 mm for the kappa no. 90 and 3.9 mm for the kappa no. 60. The average length of tracheids in the topwood, composed primarily of juvenile wood, was significantly shorter averaging 3.3 mm for the kappa no. 90 and 3.5 mm for the kappa no. 60.

To test paper properties, hand sheets were made from the sack paper and linerboard pulps. The topwood chips produced linerboard that was higher in short span compression, burst strength, tensile strength, and specific modulus compared to the linerboard made from the whole stem or CSC (table 4). The topwood hand sheets were higher in strength properties because of the higher percentage of thinner walled juvenile tracheids in topwood. The thin-walled tracheids collapsed around each other and, thus, increased bonding and corresponding higher burst, tensile, and compression strength.

The sack paper hand sheets made from the topwood chips were higher in sheet density, short span compression, burst, tensile strength, and specific modulus, but significantly lower in tear resistance than the sheets made from the whole stem or CSC (table 5). The sack paper hand sheets were significantly lower in tear resistance because of the significantly shorter tracheids in the topwood compared to that of the whole stem or CSC.

Table 4—Average properties of linerboard hand sheets manufactured from whole stem chips, chipping saw chips, and topwood chips produced from 17-year-old slash pine growing in the lower Coastal Plain

Chip source	Sheet density	Short-span compressive test	Burst index	Tensile index	Specific modulus
	kg/m^3	*N m/g*	*kPa m^2/g*	*N m/g*	*N m/g*
Whole stem chips	715	26.7	5.20	54.2	5550
Chipping saw chips	645	27.2	5.13	49.6	5260
Topwood chips	717	30.02	5.53	72.5	7010

kg/m^3 = kilograms per cubic meter; N m/g = Newtonmeters per gram; kPa m^2/g = kilopascals square meters per gram.

Table 5—Average properties of sack paper hand sheets manufactured from whole stem chips, chipping saw chips, and topwood chips produced from 17-year-old slash pine growing in the Lower Coastal Plain

Chip source	Sheet density	Tear index	Burst index	Tensile index	Specific modulus
	Kg/m³	*mN m²/g*	*kPa m²/g*	*N m/g*	*N m/g*
Whole stem chips	630	19.9	5.80	73.7	6690
Chipping saw chips	618	20.0	6.03	68.3	6320
Topwood chips	670	17.6	7.03	88.5	7570

Kg/m³ = kilograms per cubic meter; mN m²/g = milliNewtons square per gram; kPa m²/g = kilopascals square meters per gram; N m/g = Newtonmeters per gram.

SUMMARY

Slash pine wood SG is higher, wood moisture content is lower, and bark content higher than that of loblolly pine. Thus the weight-scaling factor, weight of wood, and bark per cubic foot of wood is higher for slash pine than loblolly pine. The high SG and branching habit of slash pine make it an excellent species for manufacturing dimension lumber. Because of the small diameter branches and early natural pruning, slash pine produces more No. 1 and better dimension lumber and less No. 3 and No. 4 lumber than loblolly pine. When planted at wide spacings, slash pine will produce a higher proportion of No. 1 and better lumber than loblolly pine because of its natural pruning and smaller diameter branching habit. The tracheid characteristics of slash pine make it an excellent species for linerboard and sack paper production. The lower SG, thin-walled tracheids of topwood chips produce linerboard with higher strength properties than those of whole stem or CSC. However, the whole stem and CSC produced sack paper with higher tear resistance than topwood chips because of the longer tracheids.

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